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CARBONIFEROUS FERTILE BRANCH *SPORANGIOSTROBUS FEISTMANTELII* (O. FEISTMANTEL) NĚMEJC AND ITS MIOSPORES FROM THE KLADNO BASIN, BOHEMIAN MASSIF

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Abstract. Fertile apex of *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC and its spores has been studied. Palynological study was concentrated on the variability of densospores in one sporangium as well as in sporangia from various parts of its apex. Natural morphological variability of densospores was wider than we expected. Densospores from four different positions of this apex belong to eight species of the genus *Densosporites* (BERRY) BUTTERWORTH, JANSONIUS, SMITH et STAPLIN and one species of the genus *Cristatisporites* (POTONIÉ et KREMP) STAPLIN et JANSONIUS. Basal part presents overmatured degree where almost all densospores have fallen out, middle part presents full degree of maturity with the widest morphological variability of densospores and the apical part presents relative immaturity. Fertile apexes of *S. feistmantelii* gradually matured from the basal to the apical parts. Several "circular sacks", probably single microsporangia or part of a single sporangia full of densospores, were isolated and described for the first time.

■ Central Bohemian Carboniferous Basins, lycopsida, fertile part, in situ spores, maturity degree.

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Introduction

This paper presents a description of an apical part of a fertile branch of *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC from the Kladno Basin, Central Bohemian Basins. From this fertile part several samples were taken and studied palynologically. This work has allowed a comparison of dispersed spores with their parent plants. The stratigraphical ranges of spores as well as their parent plant were compared. Palynological study concentrated on the variability of spores in one sporangium as well as in sporangia from various parts (basal, lower, middle and apical) of this apex. The studies of Carboniferous spores in situ in the Bohemian Upper Carboniferous were started by Němejc (1931, 1935, 1937, 1941) but without any detailed description of spores. Later on only the counterpart of this specimen was studied by Drábková (pers. comm.).

Previous research

The genus *Sporangiostrobus* BODE was instituted by Bode (1928). He described two species from Orzesze in the Upper Silesian Basin (Bolsovian) in Poland: *S. orzechensis* BODE with smooth densospores and *S. rugosus* BODE with sculptured ones. O. Feistmantel (1876) described Bolsovian (Westphalian) species *Sigillariostrobus feistmantelii* O. FEISTMANTEL and *S. cordai* O. FEISTMANTEL from the Kladno Basin. Both plants were also known by Corda (Němejc 1931) as *Emboliantheum truncatum* CORDA and *E. sexangulare* CORDA. Němejc (1931) re-assigned these species to the genus *Sporangiostrobus* BODE. He described *S. feistmantelii* (O. FEISTMANTEL) NĚMEJC as a bisporangiate fertile part of a branch or as a morphological interstage from branches to typical cones of lycophytes. *S. cordai* (O. FEISTMANTEL) NĚMEJC was described as a part of megasporangiate branch. Fertile branches *S. feistmantelii* (O. FEISTMANTEL) NĚMEJC are also known from Puertollano Basin, Central Spain (Late Stephanian). Wagner (1989) compared specimens from this locality with those from Central Bohemian Basins and he found them identical. According to the latest Coquels investigation (pers. comm.) Spanish specimens contain different type of megaspores than the Czech ones and they are probably of a different species. Wagner et Spinner (1976) constituted *Bodeodendron* WAGNER et SPINNER as a vegetative stem borned *Sporangiostrobus* BODE as a fertile branch or apex. *Puertollania* REMY et REMY seems to be only the ultimate stage in disarticulation of *Sporangiostrobus*, leaving only sporangia with proximal parts of sporophylls (Wagner 1985). Nowadays Wagner (pers. comm.) has compared *Bodeodendron* WAGNER et SPINNER with the genus *Omphalophloios* WHITE. Němejc (1931) described densospores from fructifications of *S. feistmantelii* of Bolsovian age from the Kladno Basin. The first palynological description of densospores in situ was given by Bharadwaj (1958) from *Porostrobus zeilleri* NATHORST from the Lower Carboniferous of Spitzbergen. He also isolated "overmacerated" densospores which were treated longer with KOH solution. They could be easily referred to as a different species. The size of "overmacerated" densospores increases to as much as double the normal one. Also the central body increases in size. He isolated central or inner bodies with three papilla, too. Densospores in situ were also described by Chaloner (1962) from *Sporangiostrobus ohioensis* CHALONER (Langsettian) from Ohio. Densospores in situ are referred to dispersed species *Densosporites solaris* BALME but the referrence was recently changed by Smith et Butterworth (1967) to genus *Cristatisporites* as the species *C. solaris* (BALME) SMITH et BUTTERWORTH. Chaloner also mentions that *C. indignabundus* (LOOSE) POTONIÉ et KREMP is very similar to *C. solaris* and that: "... a number of other species similar in varying degrees to those present in *S. ohioensis* have been described occuring as dispersed spores)" (Chaloner 1962, p. 76). Following dispersed densospores appear to be significantly similar:
Denso-sporites pannosus KNOX (Namurian), 62μm
Denso-sporites type A; Hoffmeister, Staplin et Malloy (High Dinantian), 54μm
Denso-sporites spinifer HOFFMEISTER, STAPLIN et MALLOY (High Dinantian), 32(46)48μm
Cristatisporites indignabundus (LOOSE) POTONIÉ et KREMP (Duckmantian-Bolsovian), 50(52)80μm
Cristatisporites connexus POTONIÉ et KREMP (Duckmantian), 45(56)70μm
Densosporites duriti POTONIÉ et KREMP (Duckmantian), 45(68)70μm
Cristatisporites splendidus ARTUZ (Langsettian), 45(55)63μm
Cristatisporites cf. *indignabundus* (LOOSE) POTONIÉ et KREMP; Bharadwaj 1957 (?Bolsovian), 40-55μm
Cristatisporites elegans BHARADWAJ (? Bolsovian), 38(44)48μm
Densosporites decorus (LOOSE) DYBOVÁ et JACHOWICZ (Duckmantian-Westphalian D), 55μm
Densosporites spinosus DYBOVÁ et JACHOWICZ (Namurian A-Duckmantian), 48μm
Densosporites verrucosus DYBOVÁ et JACHOWICZ (Bolsovian), 32(50)54μm
Densosporites cf. *indignabundus* ALPERN (Stephanian), 56-60μm
Densosporites cf. *indignabundus* ALPERN (Stephanian), 50-80μm
This list of dispersed densospores, closely similar to each other, supports the fact that wide natural morphological variability of densospores existed in one fructification.

Leisman (1970) isolated densospores from fructifications of *Sporangiostrobus kansanensis*

LEISMAN from coal-balls from Kansas (Pennsylvanian). He described densospores of two sizes (some of them may be aborted or still immature). Larger densospores were referred by Leisman to the dispersed genera *Radiizonates* STAPLIN et JANSONIUS (species *R. rotatus* (KOSANKE) STAPLIN et JANSONIUS or *R. aligerens* (KNOX) STAPLIN et JANSONIUS) or *Cingulizonates* (DYBOVÁ et JACHOWICZ) STAPLIN et JANSONIUS or *Vallatisporites* HACQUEBARD (spores with random dissection of the patina or merely vacuolate conditions) or *Cristatisporites* (spores with mammoidal or warty projections over a basic foveolate background).

Smaller (aborted ?) densospores can be referred to the dispersed genus *Densosporites* (species *D. simplex* STAPLIN or *D. intermedius* BUTTERWORTH et WILLIAMS or *D. rotatus* STAPLIN). Leisman was the first who described different densospore genera and species from one parent plant.

Densospores in situ belong to the dispersed species *Densosporites sphaerotriangularis* KOSANKE were isolated by Remy et Remy (1975) from *Sporangiostrobus puertollanensis* REMY et REMY from strata of Stephanian C age of Puertollano in Spain. Drábková (pers. comm.) studied the counterpart of this specimen and obtained similar results as this paper does. The latest palynological study of Spanish specimens of *Sporangiostrobus* (Coquel, pers. comm.) were made with similar results.

Material and methods

Specimen No. E 5625 collected by K. Drábek is stored in the National Museum, Prague. This specimen is placed in the collection from tuffaceous sandstone near Lubná in Kladno Basin. It comes from the Bolsovian, the Radnice Member of the Kladno Formation. Macerales, slides, SEM samples and negatives of spores are deposited in the Department of Palaeontology of the Geological Institute of the Academy of Sciences of the Czech Republic in Prague.

One rhomboid sporangium was mechanically removed from this fertile part. The sample was treated with concentrated nitric acid at room temperature for 24 hours and by potassium hydroxide (5-10%) for 12-24 hours. The residue was washed several times in water using centrifuge.

Spores in situ were examined with a light microscope as well as a scanning electron microscope (SEM). 5-15 palynological slides in glycerine jelly were made from each sample. For SEM a drop of macerale was fixed in a vacuum and coated with gold.

The cuticles of sporangium walls were obtained by maceration of sporangia in the Schulze's solution and subsequently cleared in 30% solution of KOH. Remains of a vascular system were obtained abreast with macerating of miospores.

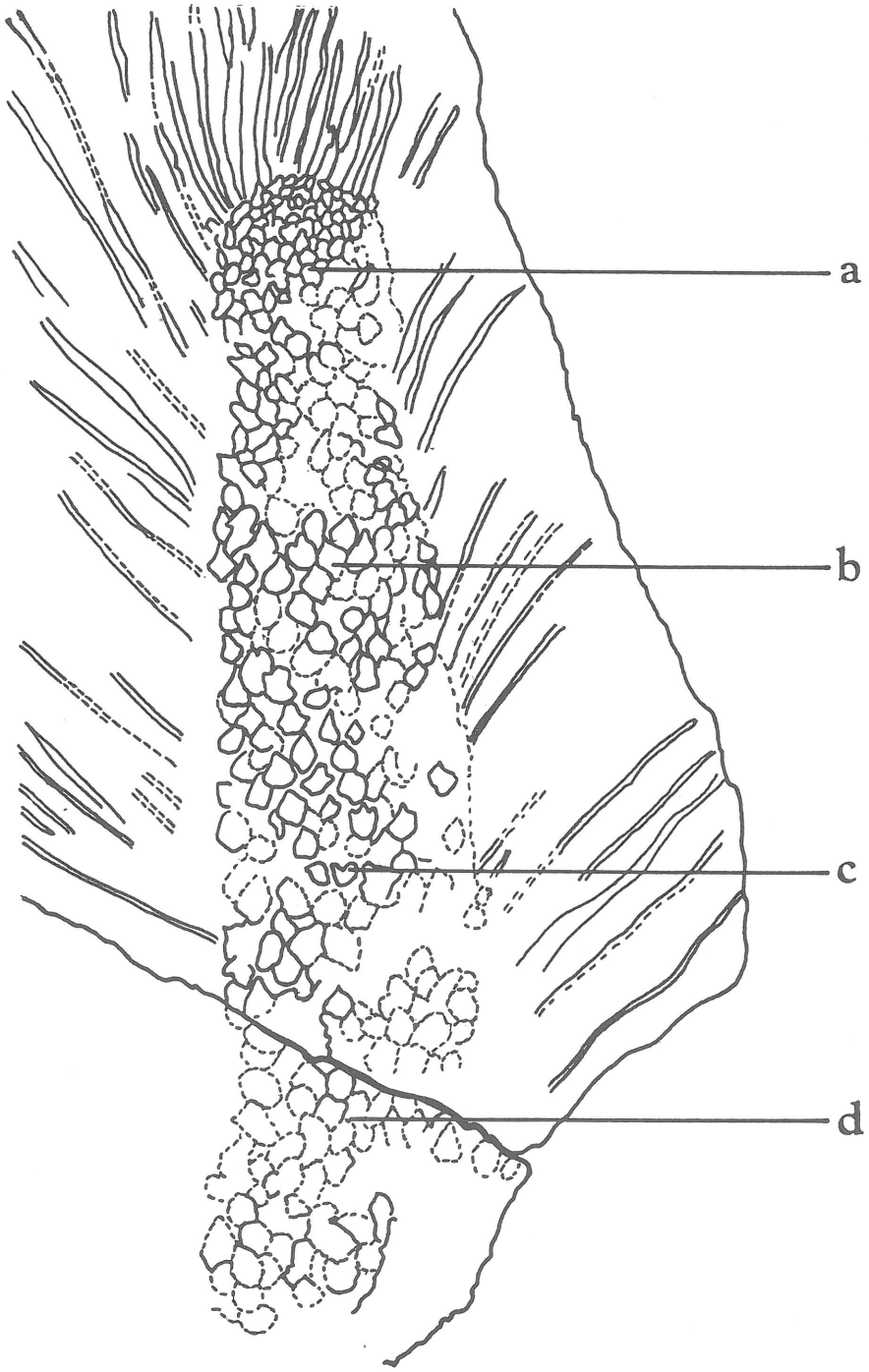
Systematic position

Class: Lycopsida
Order: Lepidocarpales
Family: Sporangiostrobaceae

Genus: ***Sporangiostrobus*** BODE, 1928

Sporangiostrobus feistmantelii (O. FEISTMANTEL) NĚMEJC, 1931
Pl. 1

Syntypes: *Sigillariaestrobus feistmantelii* O. FEISTMANTEL, 1876: 225-226, pl. 60, figs 1, 1a, 2, 2a, 3, 3a, National Museum Prague No. E 974 (fig. 2, other specimens are probably lost)
Stratum typicum: Upper Carboniferous, Bolsovian, Kladno Formation, Radnice Member
Locum typicum: Kladno Basin, Břasy



Text-fig.1 – The specimen *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC, No. NM E 5625 and observed sporangia, x 1,2
a – sporangium from apical part, b – sporangium from middle part, c – sporangium from lower part, d – sporangium from basal part

Synonyms

1856 "eine Fructähre zu *Sigillaria elegans*", Goldenberg, pl. 2, figs 18-25
1876 *Emboliatheum truncatum* CORDA ex O. FEISTMANTEL, nom. nud.
1876 *Sigillariaestrobus feistmantelii* O. FEISTMANTEL: 225, pl. 60, figs 1, 1a, 2, 2a, 3, 3a
1931 *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC: 2, pl. 1, figs 8-12, text-figs 1-6
1946 *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC; Němejc: 8
1962 *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC; Chaloner: 85
1967 *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC; Chaloner in Boureau: 663
1970 *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC; Leisman: 167
1989 *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC; Wagner: 536, text-figs 5, 8-12

Description

The studied specimen of *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC is preserved as an apical part of a flattened fertile branch or apex of a small tree. It is 15cm long, cylindrical. The width of branch is 3,5cm on the bottom and 1,5cm on the top of the specimen.

A fragment of the fertile branch is partly covered by sporangia, on the lower part the sporangia are lost. They are attached in a close spiral. Sporangium shows rounded deltoid form 4x2,5mm in the middle part of the specimen, on to the apex they are smaller. Sporangium is covered by a two cell-layer thick smooth sporangium wall. The outer layer (pl. 2, fig. 3) consists of thin-walled cells average 30μm in lenght and 13μm in width. No stomata were found. These cuticles are quite similar to those reported by Němejc (1931). The inner layer (pl. 6, figs 1-3) consists of palisade-like cells 190μm length (measured in the right angle to sporangium wall). These results are comparable with those by Leisman (1970), only the cuticle cells of *S. kansanensis* LEISMAN are a little bigger and the palisade-like cells are shorter than those of our specimen of *S. feistmantelii* (O. FEISTMANTEL) NĚMEJC.

The observed specimen shows poorly preserved and mostly incomplete distal laminae of sporophylls still attached. The lenght of simple laminae is from 3,8cm to 12,7cm (average 6,4cm), the width of laminae is about 1mm.

By macerating sporangia from the lower part of the specimen a number of remains of vascular strand were obtained. There is no evidence that they are remains of the axis vascular strand or one of the central columns of a sterile tissue extending into the sporogenous zone. These vascular strand tissues (pl. 2., figs 1, 2, 4, 5, pl. 3, figs 1, 2) are composed of tracheids with scalariform spiral thickennings.

Spores

Palynological study was concentrated on the variability of densospores in (particular) one sporangium as well as in sporangia from various parts of this apex.

Apical part

One sporangium from the apical part (see text-fig. 1) contained only densospores belonging to the dispersed species *Densosporites* cf. *spinifer* HOFFMEISTER, STAPLIN et MALLOY. These spores appeared to be of smaller forms (size average is 29μm) of the type, but otherwise they are similar to *D. spinifer*. Slides contained about 65% of tetrads and 35% of isolated densospores. All densospores in slides appear to be identical and uniform. Some variability of the distal sculpture is seen on pl. 8, figs 7, 8. Hoffmeister, Staplin et Malloy (1955, p. 386) stated in original diagnosis of *D. spinifer*: "...dense or scattered spinae, 2-6μm long, sometimes bifurcated, extremely variable in shape or disposition". It seems that this variation of distal sculpture, which can be observed on these figures, may be of natural origin.

Densosporites cf. *spinifer* HOFFMEISTER, STAPLIN et MALLOY, 1955
Pl. 8, figs 1-8

Description: Amb triangular to subtriangular, 27(29)32μm large. Laesurae extending to the margin of central body. Exine of central body finely granulate, grana about 1-2μm large. Cingulum about one fourth to one third of the radius, granulate or smooth, grana about 1-2μm large. Sculpture of distal side with spinae 1-2μm at the base and length up to 2-3μm or with densely covered spinae 3-5μm at the base and 3-6μm long (pl. 8, fig. 8).

Remarks: These spores appear to be a smaller form of the type. Their size range lies on the lower limit of the type. The size average is about 10μm smaller (about one third of the radius) than the average of spores isolated from sporangium about four centimetres to the middle. These densopores made up 100% of all specimens from this sporangium.

Middle part

Rhomboid unit from the middle part (text-fig.1) lies only about four centimetres to the apex. Rich assemblage of densospores in situ with a wide natural morphological variability was observed. Densospores in situ belong to the seven dispersed species of the genus *Densosporites* and one of the genus *Cristatisporites* were isolated from this sporangium.

Spores *Densosporites granulosus* KOSANKE made up about 79% , *D. sphaerotriangularis* KOSANKE about 7%, *D. lobatus* KOSANKE about 7%, *D. gracilis* SMITH et BUTTERWORTH about 3%, *D. spinifer* HOFFMEISTER, STAPLIN et MALLOY about 3%, *D. anulatus* (LOOSE) SMITH et BUTTERWORTH less than 1%, *D. glandulosus* KOSANKE less than 1% and *Cristatisporites* cf. *saarensis* BHARADWAJ less than 1% of all found specimens from this sporangium.

Most of densospores in situ belong to one dispersed species *Densosporites granulosus* KOSANKE. They were subtriangular, granulate with cingulum about one fifth to one fourth of the radius. They belong to dispersed species *D. granulosus* KOSANKE.

Other densospores, about one fifth of all specimens, are subtriangular with cingulum from one third to one half of the radius and with variable sculpture. The size of densospores is from 28 to 59μm with 51μm on average. The sculpture of central body is usually granulate, sometimes finely punctate, verrucate or spinate. The sculpture of cingulum is usually granulate or opaque, sometimes laevigate, verrucate, spinate or vermiculate.

Two types of damaged densospores (pl. 4, figs 3, 4, 6, 7) occured in this assemblage. The first type (pl. 4, figs 3, 4) is of subtriangular shape and from 30 to 45μm large. Most of the morphological features and characteristics disappeared. The exine is finely granulated with irregular rests of exoexine. There is no difference between the central body and cingulum. All sculpture elements like coni, verrucae or cristae disappeared. These damaged densospores made up less than 1% of all specimens from this sporangium.

The second type of damaged densospores (pl. 4, figs 6, 7) is of subtriangular shape and from 40 to 50μm large. The cingulum is smooth and about one third of the radius. The central body probably absent (pl. 4, fig.7). This type made up less than 1% of all found specimens in assemblage from the middle sporangium.

Sometimes several isolated central bodies of densospores occur in assemblage from this sporangium (pl. 4, fig. 5). They are of subtriangular shape and from 20 to 28μm large. Exine is laevigate and about μm thick and of a very light colour. Laesurae extends to the margin.

Several (about ten) "circular sacks" occured in slides from this sporangium (pls 6, 7). They are circular, from 160 to 488μm large with size average about 300μm. The smallest one is 160x160μm large and the biggest one 480x380μm large. These "sacks" were full of densospores. Sometimes they have ripened (pl. 7, figs 2, 3) and we can see that separate densospores have been fallen out.

Densosporites granulosus KOSANKE, 1950
Plate 3, fig. 3

Holotype: *Denso–sporites granulosus* KOSANKE, 1950, Pl. 6, fig. 8
Type locality: Gallatin County, Illinois, U. S. A

Diagnosis: (from Kosanke 1950, p. 32) "Spores are radial trilete, oval to round in transverse outline and with occasional folds on the proximal surface of the spore.... the known size variation is from 45 to 56µm. The proximal surface of the spore coat is covered with small blunt granulose structures. The equatorial area is opaque with minor spine-like projections located at the equator of the spore. The trilete mark is not prominent and the rays sometimes extend into the equatorial portion of the spore coat."

Description: Amb subtriangular 43(55)58µm. Laesurae not always visible extending to the margin of central body. Exine of central body densely granulate, grana about 2µm large. Cingulum about one fifth to one fourth of the radius, usually opaque, sometimes with minor grana about 2µm large. Margin undulate with protruding grana.

Densosporites lobatus KOSANKE, 1950

Pl. 3, figs 7, 8

Holotype: *Denso–sporites lobatus* KOSANKE, 1950, Pl. 6, fig. 4
Type locality: Gallatin County, Illinois, U. S. A

Diagnosis: (from Kosanke 1950, p. 32, 33) "Spores are radial, thought to be trilete and oval to roundly triangular... the known size variation is from 34 to 55µm. The proximal and distal portions of the spore coat are actually vermiculate, appearing reticulate when not in perfect focus. The equatorial portion of the spore coat is not a homogenous opaque structure but rather consits of an essentially opaque area to the margin of the spore wall. The peripheral margin... is sharply lobbed to nearly clefted, thus the margin is irregular in outline although the apexes are somewhat parallel to the outline of the spore coat in transverse plane."

Description: Amb subtriangular, 35(40)44µm large, laesurae of the trilete mark extending to the margin of central body. Central body finely granulate, grana about 1-2µm large. Cingulum about one third to one half of the radius with inner dark ring and verrucae or spinae parallel to the outline of the central body. Spinae are about 2-4µm high and about 1-2µm at the base. Outer light ring is less verrucate or spinate with the same sculpture as the inner ring.

Densosporites sphaerotriangularis KOSANKE, 1950

Pl. 3, figs 11-13

Holotype: *Denso–sporites sphaerotriangularis* KOSANKE, 1950, Pl. 6, fig. 7
Type locality: Williamson County, Illinois, U. S. A.

Diagnosis: (from Kosanke 1950, p. 33-34) "Outline rounded triangular. Proximal and distal central areas ornamented with widely spaced papillae. Tetrad mark distinct, 16-18µm long, extending into equatorial portion. Equatorial portion varying from 12,5 to 14,7µm wide, thickest at inner margin, translucent at equator - the two portions sharply contrasted.... Folding lacking except at inner margin of thick wall."

Description: Amb subtriangular, 35(40)45µm large, laesurae of trilete mark extending to the inner portion of the cingulum. Exine of central body smooth or finely granulate, grana about 1-2µm large. Cingulum about one third to one half of total diameter, often smooth, granulate or verrucate. Margin smooth or undulate with protruding verrucae.

Densosporites gracilis SMITH et BUTTERWORTH, 1967

Pl. 3, figs 9, 10

Holotype: *Densosporites gracilis* SMITH et BUTTERWORTH, 1967, Pl. 19, fig. 7
Type locality: South Derbyshire Coalfield, England
Diagnosis: (from Smith et Butterworth 1967, p. 240): "Amb round to subtriangular or

oval. Laesurae flexuose, extending almost to equator of spore. Cingulum (about 37% of total diameter) laevigate, granulate, vermiculate, or having small spinae, also often lobate and sometimes with dissections. Outline irregular. Central area granulate with dissections, or vermiculate."

Description: Amb subtriangular to subcircular, 28(38)44µm large. Laesurae of trilete mark extending to the margin of central body. Exine of central body finely granulate, grana about 2µm large. Cingulum about one third of total diameter, granulate or vermiculate. Sculpture elements about 2-3µm large. Outline irregular.

Densosporites spinifer HOFFMEISTER, STAPLIN et MALLOY, 1955

Pl. 4, figs 1, 2

Holotype: *Densosporites spinifer* HOFFMEISTER, STAPLIN et MALLOY, 1955, Pl. 36, fig. 17

Type locality: Webster County, Kentucky, U. S. A.

Diagnosis: (from description in Hoffmeister, Staplin et Malloy 1955, p. 386) "Outline convexly triangular. Trilete rays not distinct, extending into equatorial region. Thickened equatorial region almost opaque, thinning only slightly at outer margin. Body coarsely granulate. Equatorial region with dense or scaterred spinae, 2-6µm long, sometimes bifurcated, extremely variable in shape and disposition, spinae at margin."

Description: Amb subtriangular, 30(38)45µm large. Laesurae of trilete mark extending to the outer part of central body. Central body verrucate, verrucae about 2-3µm large. Cingulum about one fourth or one third of total diameter, verrucate or spinate. Verrucae or spinae of the same size as central body. Margin undulate with protruding verrucae or spinae.

Densosporites anulatus (LOOSE) SMITH et BUTTERWORTH, 1967

Pl. 3, fig. 6

Holotype: *Sporonites anulatus* LOOSE in POTONIÉ, IBRAHIM et LOOSE, 1932, Pl. 18, fig. 44

Type locality: Bismarck Seam, Ruhr Coalfield, Germany

Diagnosis: (translated from Potonié et Kremp 1956, p. 112) "Cingulum relatively uniform and smooth, having scaly structure. Amb smooth. Central area relatively much lighter than cingulum. Infragranulation obscure. Tetrad mark scarcely discernible".

Description: Amb subtriangular, 38x32µm large, laesurae of trilete mark extending to the margin of central body. Central body infragranulate, cingulum narrow, about one third of total diameter, laevigate. Margin smooth.

Densosporites glandulosus KOSANKE, 1950

Pl. 3, fig. 5

Holotype: *Denso–sporites glandulosus* KOSANKE, 1950, Pl. 6, fig. 3

Type locality: Fulton County, Illinois, U. S. A.

Diagnosis: (from Kosanke 1950, p. 32) "Spores are radial, trilete (?), originally spheroid ... the known size range is from 25 to 38µm. The proximal and distal portions of the spore coat are minutely granulose as seen with the aid of oil imersion, and they are also scattered about a number of stalked granulose structures. The glandulose projections average about 4,2µm in length, 1-2µm in apex and usually much less at the base".

Description: Amb subtriangular, 42x39µm large, laesurae of trilete marks indistinct. Central body granulate to verrucate. Cingulum about one third of total diameter, strongly granulate

to verrucate, margin undulate. Sculpture elements about 2-4,5µm large, sometimes thinner at the base.

Cristatisporites cf. *saarensis* BHARADWAJ, 1957
Pl. 3, fig. 4

Holotype: *Cristatisporites saarensis* BHARADWAJ, 1957, Pl. 27, fig. 24
Type locality: Mine Maybach, Saar Coalfield, Germany

Diagnosis: (from Bharadwaj 1957, p. 105) "Size 33-45 µm, roundly triangulate, trilete rays more or less reaching the equator, cingulum width about one third radius length, exine ornamented with well developed coni."
Description: Amb subtriangular, 40x44µm large. Laesurae of trilete mark extending to the margin of central body. Central body granulate to verrucate, grana or verrucae about 3-6µm large. Cingulum about one third of total diameter with inner dark ring with protruding grana and verrucae and outer light ring with the same sculpture. Margin undulate.
Remarks: This miospore differs from *C. saarensis* BHARADWAJ by less dense sculpture of proximal hemisphere but otherwise it is similar to *C. saarensis* BHARADWAJ.

Lower part

Rich densospore assemblage were described from a sporangium from the lower part (text-fig. 1). Densospores in situ belong to the five dispersed species of the genus *Densosporites*. Spores *Densosporites sphaerotriangularis* were 45(58)71µm large and they made up 93% of all specimens here, spores *D. spinifer* were 45(48)50µm large, they made up about 5%, spores *D. lobatus* were 50(57)62µm large, they made up about 1%, spores *D. granulosus* were 48(54)59µm large, they made up less than 1% and spores *D. gracilis* were 44(46)48µm large, they made up less than 1% of all specimens here. All species described here were also isolated from the previous sporangium about three centimetres to the apex, but they were larger in size.

Basal part

Two sporangia from the basal part (text-fig. 1) contained only very rare and sporadic finds (only 10 specimens in 20 slides) of densospores belonging to the dispersed species *Densosporites pseudoannulatus* BUTTERWORTH et WILLIAMS. Slides were full of various plant remains such as cuticles or tracheids (pl. 2, figs 1-5, pl. 3, figs 1, 2).

Densosporites pseudoannulatus BUTTERWORTH et WILLIAMS, 1958
Pl. 2, fig. 6

Holotype: *Densosporites pseudoannulatus* BUTTERWORTH et WILLIAMS, 1958, Pl. 19, fig. 11
Type locality: West Fife Coalfield, Scotland

Diagnosis: (from Butterworth et Williams 1958, p. 379) "Amb round to subtriangular. Laesurae not always seen, rays simple, extending to edge of central area. Margin smooth or finely serrated. Central area thin, finely granulate, frequently showing accurate folding at the margin. Cingulum massive, breadth roughly equal to radius of central area, uniform in thickness, smooth to slightly spinose and often with characteristic radial fractures on the interradial margin."
Description: Amb subtriangular, 52x58µm large. Laesurae not visible. Central body finely punctate. Cingulum laevigate about one third of total diameter. Margin smooth.

Discussion

It seems that fertile branches of *S. feistmantelii* matured gradually from the basal to the apical parts. Densospores from the apical sporangium are almost twice as small as than densospores situated about four centimetres to the middle. Large number of tetrads (65%), small size of densospores and low degree of variability (one species) provide evidence of the relative immaturity of this apical sporangium.

The richest assemblage with the widest variability of densospores was isolated from the sporangium taken from the medial part of a fertile branch. Most of densospores (almost 80%) belong to the one dispersed species. The smaller part of them (about 20%) was more or less different and belonged to six dispersed species of the genus *Densosporites* and to one of the genus *Cristatisporites*. The presence of different densospore genera and species in one sporangium is not unusual because some authors have published or produced similar results (Leisman 1970, Drábková pers. comm., Wagner pers. comm.). This morphological variability could be of natural origin or it can depend on the fossilisation or preservation of spores in situ. We can suppose that 100% of spores in this matured sporangium were not identical. Some degree of the natural variability probably existed among spores in one sporangium as well as in sporangia from various positions of one fertile branch. This fact is stressed by using the system of dispersed spores for the classification of spores in situ. In the case of dispersed densospores this system is often based on the less important morphological features as the size of spores, number, shape, size, position and density of sculpture elements. The main morphological features are the same. This sporangium probably represents the full degree of maturity.

Several isolated central bodies of densospores are recorded in slides from the middle sporangium. They are smooth with more or less visible trilete mark. The same parts of densospores were described also by Bharadwaj (1958) but with three papillae.

Two types of damaged densospores isolated from this middle sporangium are probably products of maceration techniques. The second type of this damaged densospores is very similar to Bharadwaj's (1958) "overmacerated" densospores. But in this case all spores were macerated in the same way and for the same period of the time. The central body fell out or it was destroyed.

Several "circular sacks" full of densospores isolated from the middle part are unusual. Authors who studied parent plant of densospores including Feistmantel, Bode, Němejc, Bharadwaj, Chaloner, Leisman, Remy et Remy or Wagner have not described anything like this. These "sacks" contained a number of densospores inside. We suppose that these „sacks" may be isolated microsporangia or their parts.

Similar densospore assemblage with densospores belong to the five dispersed species of the genus *Densosporites* was isolated from the lower part. Most of densospores (about 93%) belong to one dispersed species. This sporangium represents full degree of maturity. Two sporangia from the basal part of this apex contained very sporadic finds of densospores. All spores belong to the one dispersed species. They are cingulate without any morphological features as laesurae, grana, verrucae, spinae or coni. Slides were full of various plant remains esp. tracheids or cuticles. These sporangia probably represent an overmatured degree where all the spores had fallen out and only various plant rests such as cuticles or tracheids remained. Densospores and some of their parent plants with the stratigraphical ranges are shown in the Tab. 1.

All densospores isolated from this apex of a fertile branch have identical stratigraphical ranges and geographical distribution in dispersed spore assemblages in the central and western Bohemian Carboniferous Basins. They are most common within the Bolsovian (the Radnice Member of the Kladno Formation) and less abundant within the Westphalian D (the Nýřany Member) and Stephanian B (the Slaný Formation). Their parent fertile branch *S. feistmantelii* is common in the lower part of Bolsovian (the Upper Radnice Coal of the Radnice Member, in stratigraphically younger strata of the Radnice Member it is rare).

Sporadic finds of dispersed densospores within the Westphalian D and Stephanian B indicate a possible occurrence of the genus *Sporangiostrobus* in these stratigraphically younger units although no remains of *Sporangiostrobus* have been found in the Bohemian Upper Carboniferous strata so far. *S. feistmantelii* (O. FEISTMANTEL) NĚMEJC is known from Upper Stephanian in Spain (Wagner 1985), too. According to the latest palynological inves-

tigation made by Coquel (pers. comm.) Spanish specimens contain different megaspores and therefore they are of different species. Parent plants of densospores have a long stratigraphical range from the Lower Carboniferous (*Porostrobus zeilleri*, Bharadwaj 1958) to the Stephanian C (*Sporangiostrobus puertollanensis*, Remy et Remy 1975) and a wide geographical distribution.

It seems that densospores in matured sporangium have wider natural morphological variability than we expected. Using the system of dispersed spores for classification of spores in situ we often describe different dispersed genera and species. Classification of dispersed densospores often depends on their fossilisation or preservation.

Often only a small morphological variation, as the size of spores or number, size, shape, position or density of sculptured elements gives the reason for the description of a new dispersed densospore species. Different shape or size of sculptured elements could exist among densospores in one sporangium or in one fertile part and it need not be the reason for the existence of a new or different dispersed densospore species. Also the different size of spores can be of natural origin. As we can see above, small spores can represent a younger degree of maturity than larger spores representing full degree of maturity. Such information about spores in situ and their parent plants were not known when the descriptive morphological system of dispersed spores originated. Today we know more and more facts about these relationships.

Different dispersed densospore genera and species isolated from one parent plant are not unusual. This observation is supported by results of some other authors (Leisman 1970, Drábková pers. comm., Wagner pers. comm.). Erecting of groups of dispersed densospore genera or species isolated from one plant could present a truer picture of spores and their parent plants in general.

Conclusions

This paper provides some new information about a fertile branch of the small tree *Sporangiostrobus feistmantelii* (O. FEISTMANTEL) NĚMEJC and its spores from the Kladno Basin in the Bohemian Upper Carboniferous strata. Palynological study was concentrated on the variability of spores in one sporangium as well as sporangia from various parts of this branch. According to the palynological results it seems that *S. feistmantelii* matured gradually from the basal to the apical parts. Spores belong to different dispersed densospore genera and species were isolated from one sporangium as well as sporangia from various part of this branch. Densospores from the apical sporangium represent relative immaturity and they were almost twice as small as than densospores from sporangium about four centimetres to the middle. The widest natural morphological variability of densospores (belonging to the seven dispersed species of the genus *Densosporites* and one of the genus *Cristatisporites*) were observed in assemblage from the middle and fully matured sporangium. Several "circular sacks" full of densospores isolated from the middle part may be parts of single microsporangia. Wide variability of densospores (belonging to the five dispersed species of the genus *Densosporites*) were also observed in assemblage from the lower part. Basal sporangia represent the overmature degree where almost all the spores had fallen out and only various plant residues remained.

All densospores isolated from this fertile branch have the identical stratigraphical ranges and geographical distribution in dispersed spore assemblages in Bohemian Upper Carboniferous strata. Results from other regions explain the discrepancy between the stratigraphical ranges of *S. feistmantelii* (Duckmantian-Bolsovian) and its spores (Duckmantian-Stephanian). The genus *Sporangiostrobus* is known from Spain (Wagner 1985) in much younger strata (Stephanian C). Consequently we can suppose the existence of this genus in Stephanian strata in the central and western Bohemian Carbonifreous basins on the basis of the presence of its spores in dispersed spore assemblages of Westphalian D and Stephanian age. Undoubtedly this genus was present there during the Westphalian D and the Stephanian although up to now we have not any macrofossil evidence.

It seems that densospores in matured sporangium had a wider natural morphological variability than we expected. Erecting groups of different dispersed densospores genera and species isolated from one plant could give us a truer picture about spores and their parent plant in general.

Explanation of Table: Species of *Sporangiostrobus* BODE, their miospores and stratigraphical position

PARENT PLANT	DENSOSPORES	STRATIGRAPHICAL RANGE	AUTHOR
Sporangiostrobus orzechensis BODE	*Densosporites spp.*	Bolsovian	BODE 1928
Sporangiostrobus rugosus BODE	*Densosporites spp.*	Bolsovian	BODE 1928
Sporangiostrobus feistmantelii (FEISTMANTEL) NĚMEC	*?Densosporites sphaerotriangularis* KOSANKE	Bolsovian	NĚMEJC 1931
Porostrobus zeilleri NATHORST	*Densosporites covensis* BERRY	Lower Carboniferous	BHARADWAJ 1958
Sporangiostrobus ohioensis CHALONER	*Cristatisporites solaris* (BALME) SMITH et BUTTERWORTH	Langsettian	CHALONER 1962
Sporangiostrobus kansanensis LEISMAN	*Radiizonates rotatus* (KOSANKE) STAPLIN et JANSONIUS *Radiizonates aligerens* (KNOX) STAPLIN et JANSONIUS *Radiizonates aligerens* (KNOX) STAPLIN et JANSONIUS *Cingulizonates spp.* *Vallatisporites spp.* *Cristatisporites spp.* *Densosporites simplex* STAPLIN *Densosporites intermedius* BUTTERWORTH et WILLIAMS *Densosporites rotatus* STAPLIN	Pennsylvanian	LEISMAN 1970
Sporangiostrobus puertollanensis REMY et REMY	*Densosporites sphaerotriangularis* KOSANKE	Stephanian C	REMY et REMY 1975
Sporangiostrobus feistmantelii (FEISTMANTEL) NĚMEJC	*Densosporites cf. spinifer* HOFFMEISTER, STAPLIN et MALLOY *Densosporites spinifer* HOFFMEISTER, STAPLIN et MALLOY *Densosporites granulosus* KOSANKE *Densosporites lobatus her* KOSANKE *Densosporites sphaerotriangularis* KOSANKE *Densosporites glandulosus* KOSANKE *Densosporites pseudoannulatus* BUTTERWORTH et WILLIAMS *Densosporites anulatus* (LOOSE) SMITH et BUTTERWORTH *Densosporites gracilis* SMITH et BUTTERWORTH *Cristatisporites cf. saarensis*	Bolsovian	BEK et STRAKOVÁ herein
sporangiostrobus feistmantelii (FEISTMANTEL) NĚMEJC	*Densosporites lobatus* KOSANKE *Cristatisporites indignabundus* (LOOSE) POTONIE et KREMP *Cristatisporites solaris* (BALME) POTONIE et KREMP *Cristatisporites saarensis* BHARADWAJ	Bolsovian	BEK et OPLUŠTIL (in prep.)

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EXPLANATION OF PLATES:

Plate 1

Sporangiostrobus feistmantelii (O. FEISTMANTEL) NĚMEJC, No. NM E 5625, × 1

Plate 2

fig. 1 - remain of vascular strand system, × 300
fig. 2 - dtto, × 300
fig. 3 - cuticle preparation of sporangium wall, × 100
fig. 4 - remain of vascular system, × 500
fig. 5 - dtto, × 500
fig. 6 - *Densosporites pseudoannulatus,* × 500

Plate 3

fig. 1 - remain of vascular strand system, × 300
fig. 2 - dtto, × 500
fig. 3 - *Densosporites granulatus*, × 500
fig. 4 - *Cristatisporites* cf. *saarensis,* × 500
fig. 5 - *Densosporites glandulosus,* × 500
fig. 6 - *Densosporites anulatus,* × 500
fig. 7 - *Densosporites lobatus*, × 500
fig. 8 - *Densosporites lobatus* - tetrade, × 500
fig. 9 - *Densosporites gracilis*, × 500
fig. 10 - *Densosporites gracilis* - tetrade, × 500
fig. 11 - *Densosporites sphaenotriangularis,* × 500
fig. 12 - dtto, × 500
fig. 13 - *Densosporites sphaenotriangularis* - tetrade, × 500

Plate 4

fig. 1 - *Densosporites spinifer*, × 500
fig. 2 - *Densosporites spinifer* - tetrade, × 500
fig. 3 - damaged densospore, × 500
fig. 4 - dtto, × 500
fig. 5 - isolated central body of densospore, × 500
fig. 6 - damaged densospore, × 500
fig. 7 - dtto, × 1000
fig. 8 - *Densosporites* sp. - lateral view, × 1000
fig. 9 - *Densosporites sphaenotriangularis*, × 1000
fig. 10 - *Densosporites* sp. - lateral view, × 1000
fig. 11 - *Densosporites spinifer*, × 1000
fig. 12 - *Densosporites* sp. - tetrade, × 1000

Plate 5

fig. 1 - *Densosporites* sp. - damaged tetrade, × 700
fig. 2 - dtto - detail, × 2000
fig. 3 - *Densosporites granulatus*, × 1400
fig. 4 - *Densosporites* sp. - distal hemisfere, × 1000
fig. 5 - dtto - damaged tetrade, × 850
fig. 6 - dtto - detail, × 2000

Plate 6

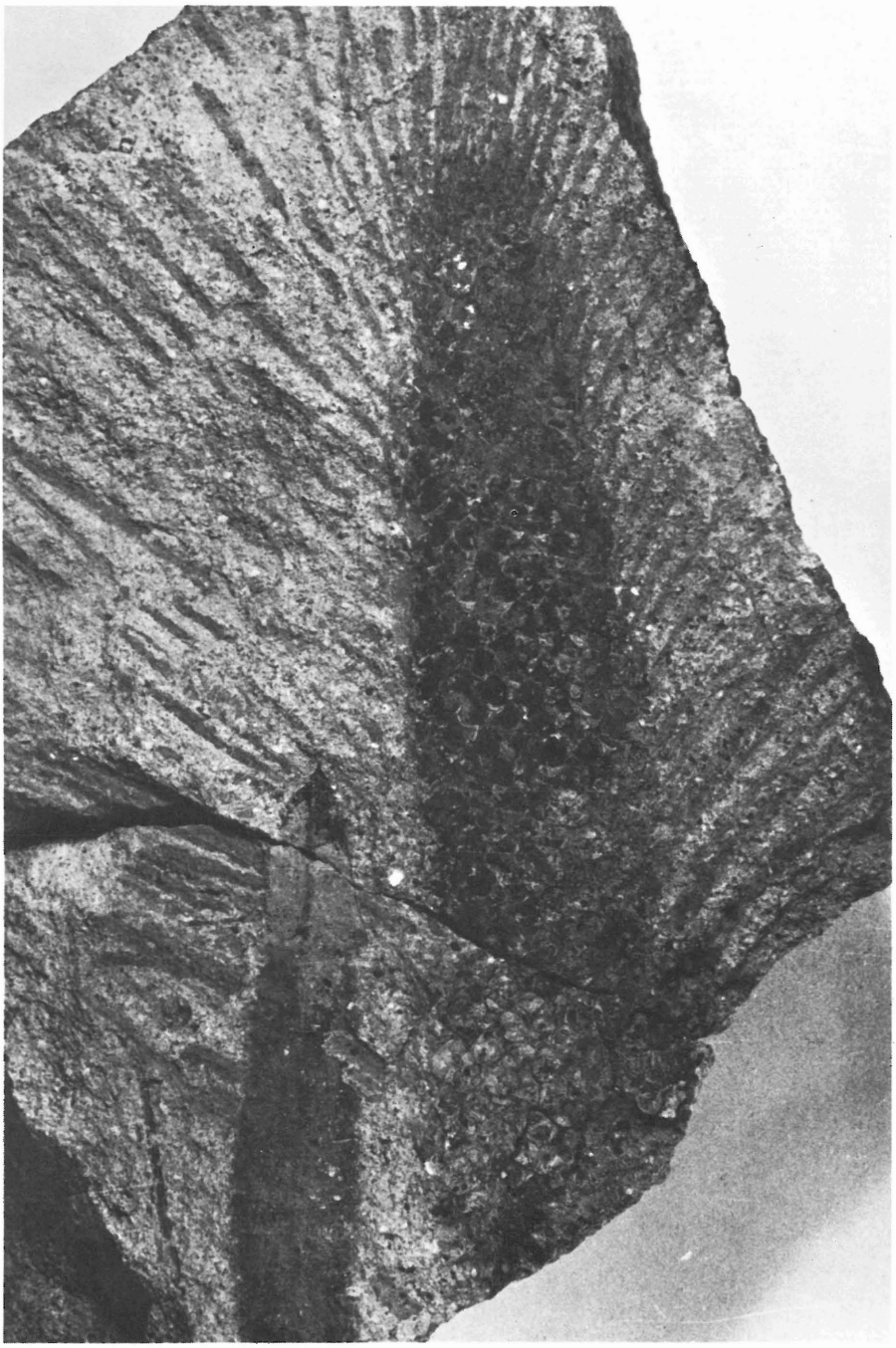
fig. 1 - part of sporangium - "circular object" full of densospores, × 100
fig. 2 - palisadel ike tissue of sporangium wall, × 800
fig. 3 - part of sporangium - "circular object" - detail, × 800

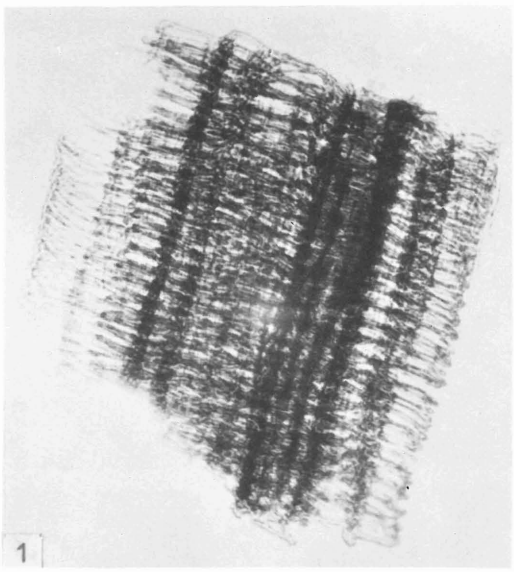
Plate 7

fig. 1 - "circular object" - part of sporangium, × 70
fig. 2 - ripened "circular object", × 70
fig. 3 - ripened "circular object" - densospores are falling out, × 250

Plate 8

fig. 1 - *Densosporites* cf. *spinifer*, × 500
fig. 2 - *Densosporites* cf. *spinifer* - tetrade, × 500
fig. 3 - dtto, × 500
fig. 4 - mass of *Densosporites* cf. *spinifer*, × 750
fig. 5 - *Densosporites* cf. *spinifer*, × 1250
fig. 6 - dtto, × 1500
fig. 7 - *Densosporites* cf. *spinifer* - tetrade, × 1250
fig. 8 - *Densosporites* cf. *spinifer* - tetrade, × 1300

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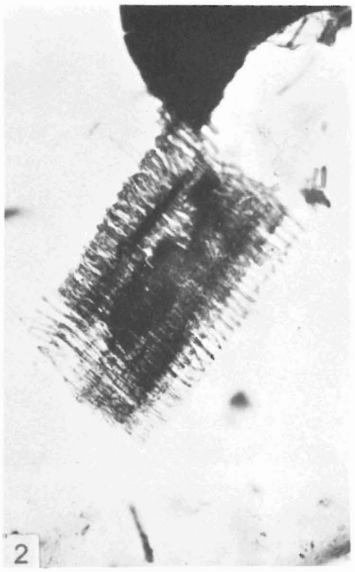
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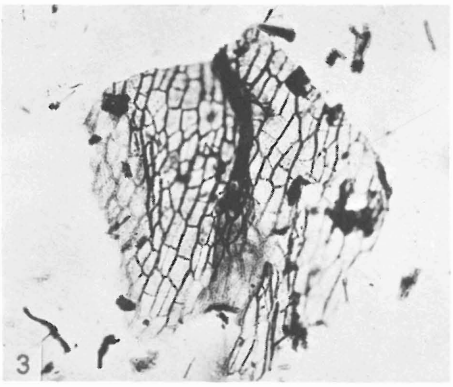
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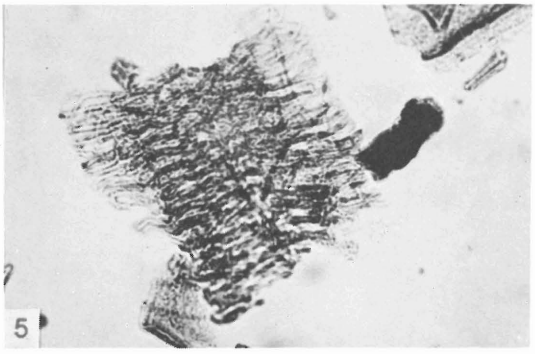
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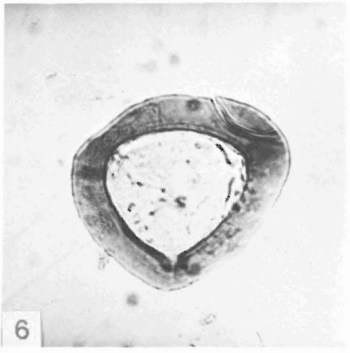
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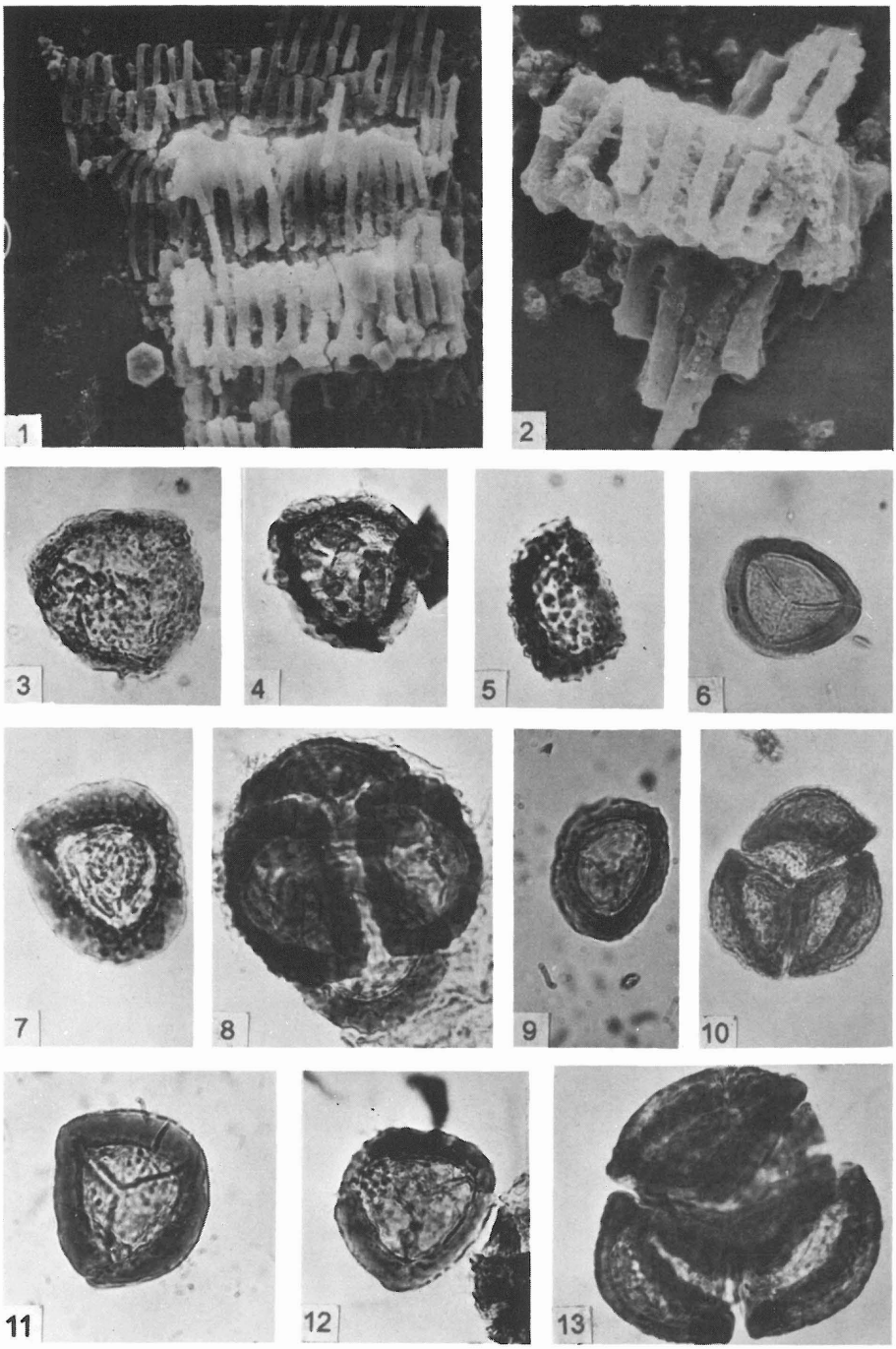
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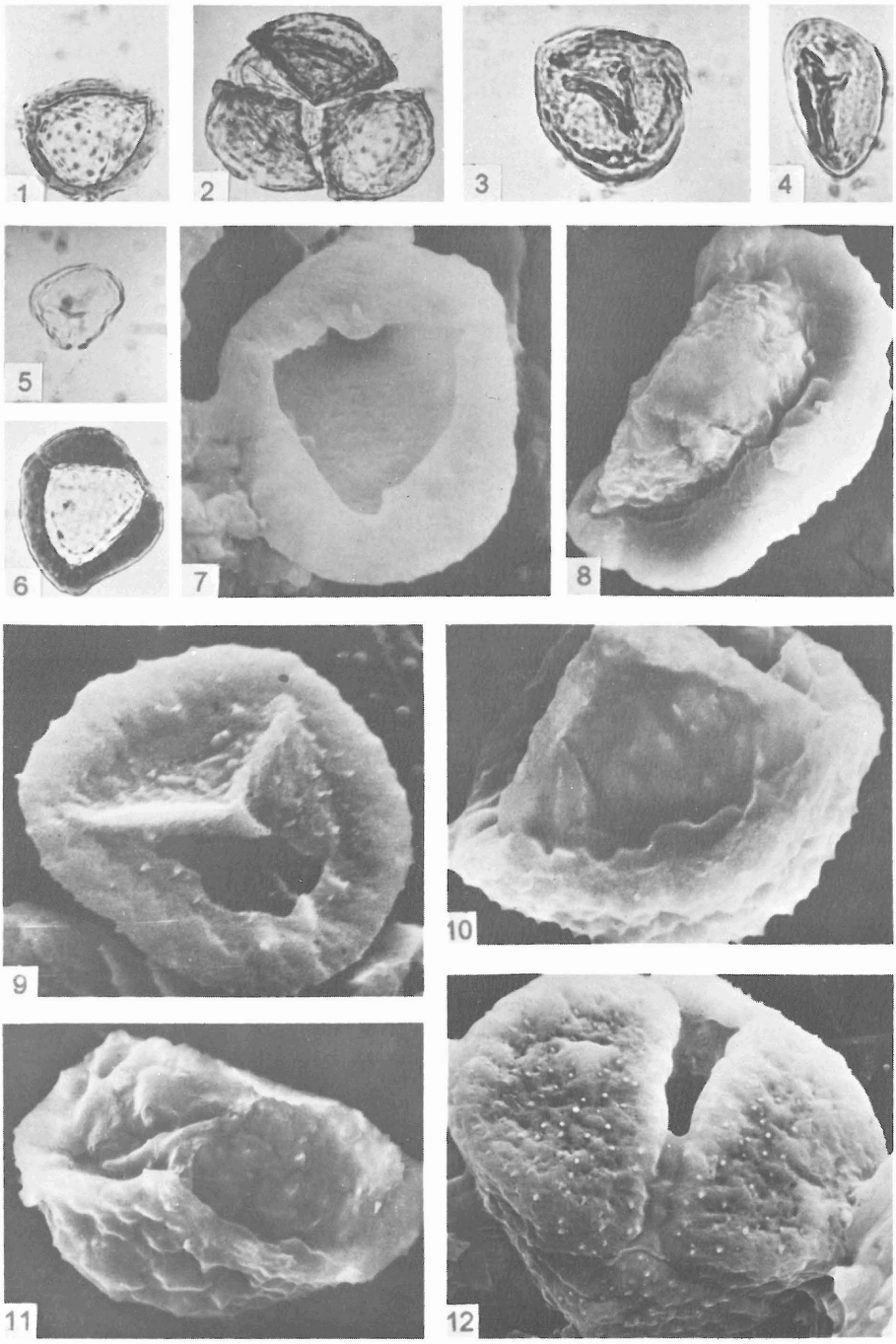
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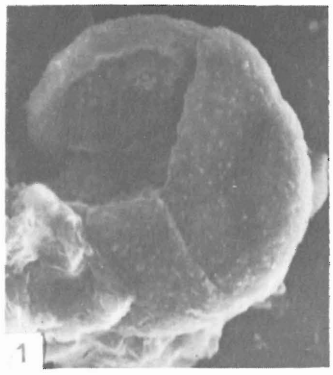
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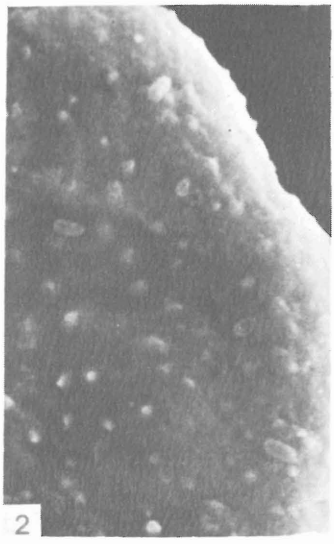
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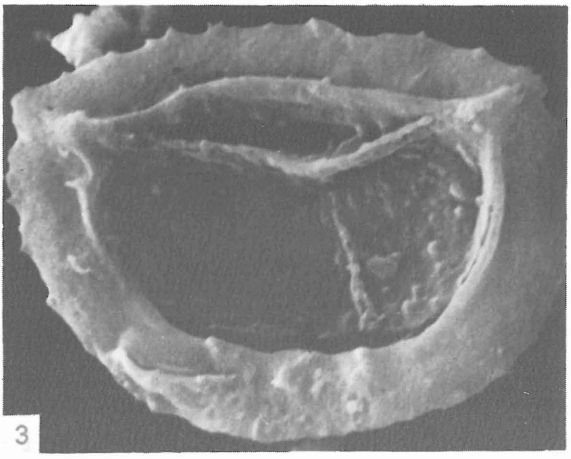
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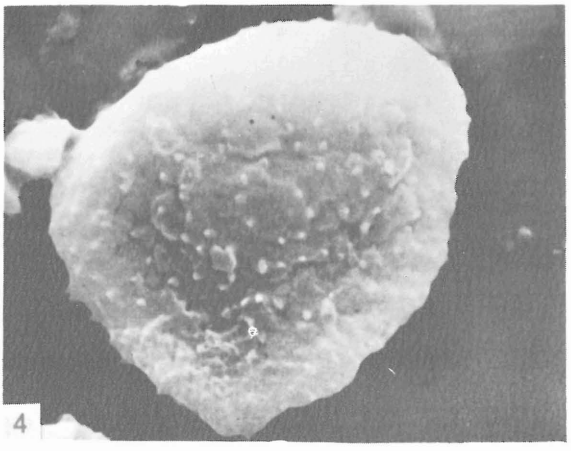
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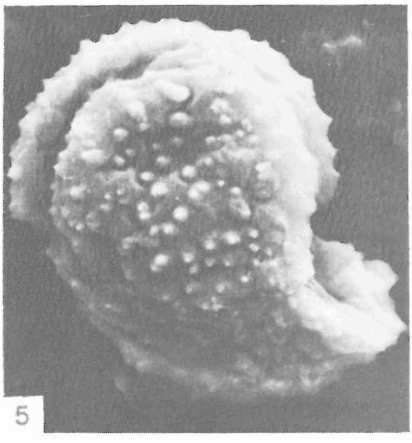
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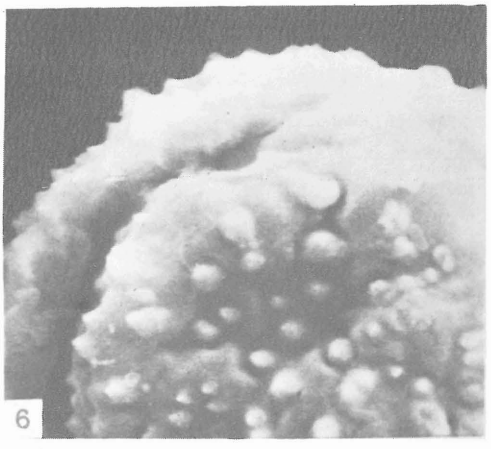
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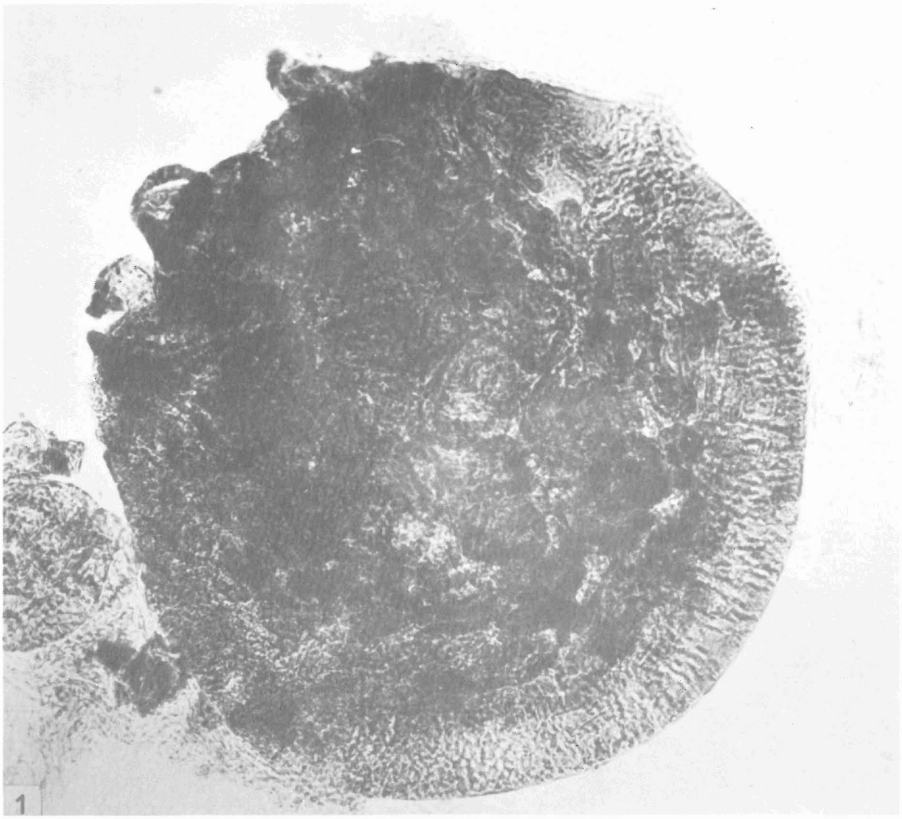
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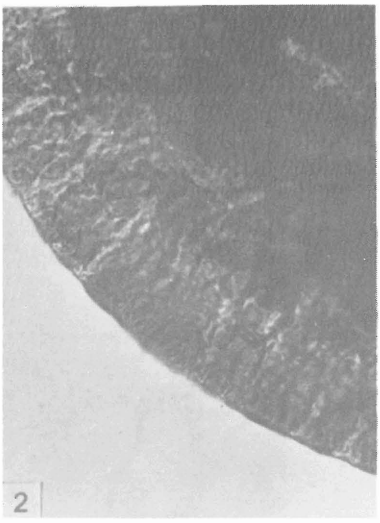
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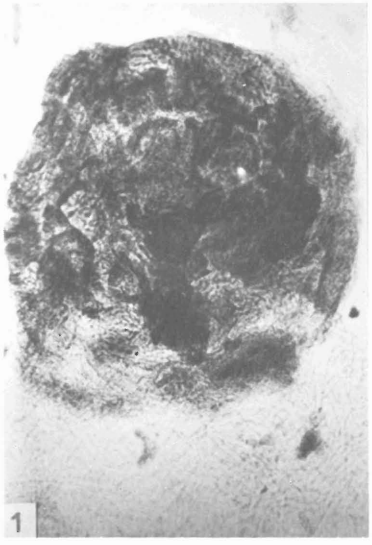
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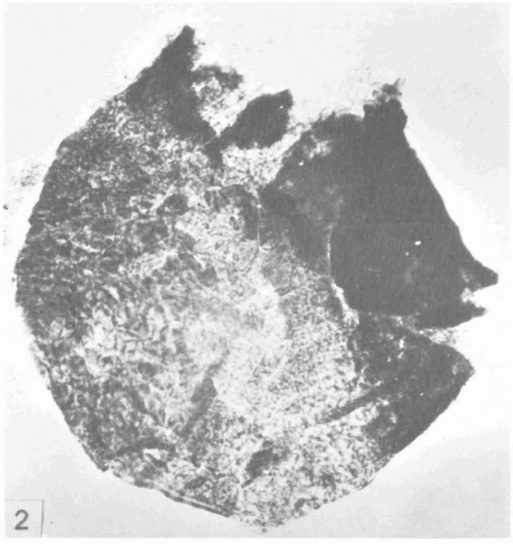
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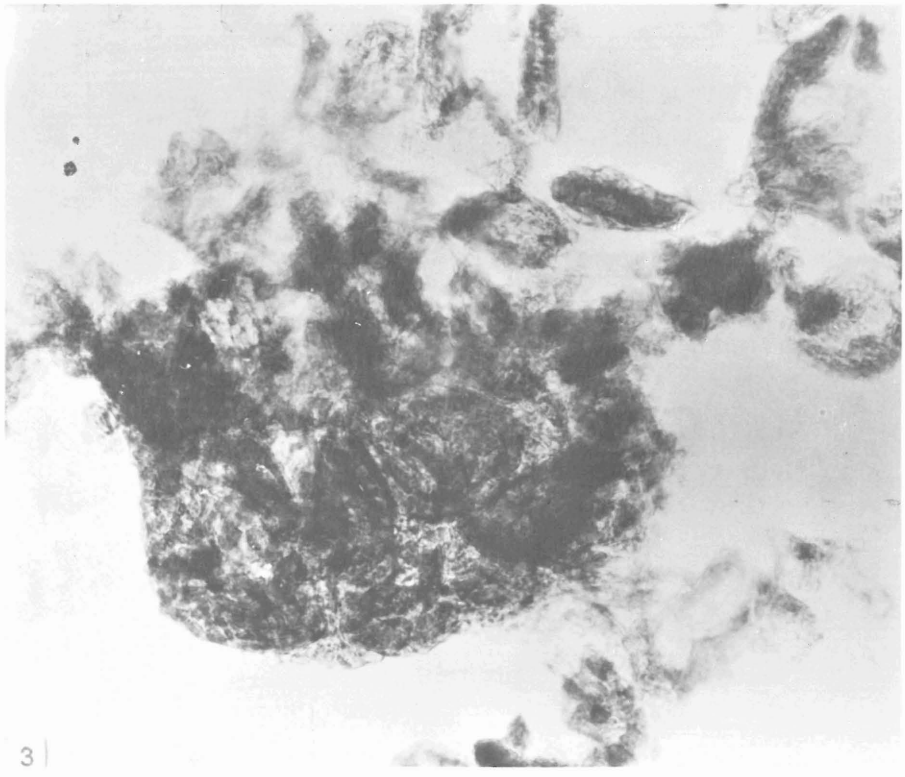
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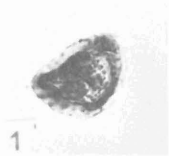
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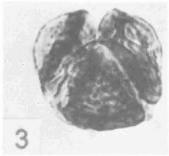
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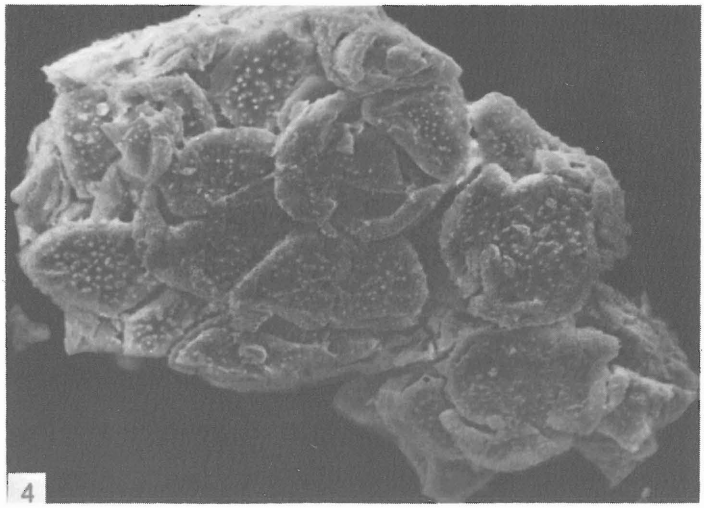
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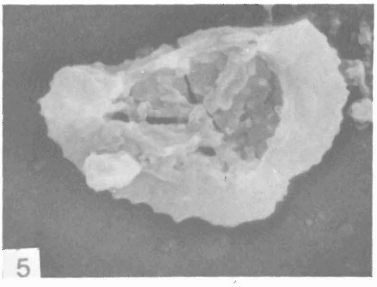
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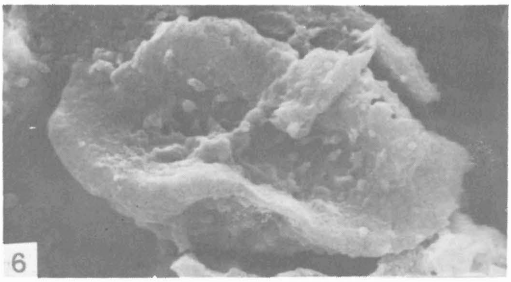
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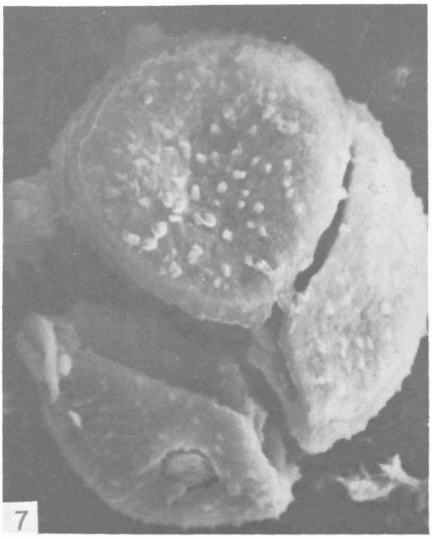
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